

Economics of Soil Erosion: Tillage/Rotation System, Dredging Costs, and Boater Value Loss in Ohio

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Introduction

Soil erosion and its resulting sedimentation problems are major concerns across the U.S. including Ohio. Detached sediment, chemicals, nutrients, and animal wastes are deposited by agricultural runoff into surface waters (18). These pollutants fill reservoirs, block navigation channels, affect aquatic plant and animal life, reduce navigation opportunities, and often endanger human health (14). Sediment appears to be the largest (by volume) impact of agriculturally derived pollutants in domestic surface water. Farmland erosion imposes external or off-site costs on a variety of receptors. Nationally, Clark et. al.(1985) estimates off-farm costs between \$3 and \$13 billion with a point estimate of \$6.1 billion; Ribaud (1986) estimates the off-farm costs at \$7.1 billion. Both estimates include off-farm costs from the erosion of sediment, nutrients and chemicals into water.

Over the past several decades, the Army Corps of Engineers and the Ohio Department of Natural Resources have undertaken dredging operations to remove sediment in Ohio waterways. The goal is to assure unencumbered navigation and adequate water supplies, when and where they are demanded, for the multiple purposes water serves (5). Many sources and impacts of sediment exist, but this research effort will deal only with the boating impacts and dredging costs of sediment from cropland runoff which accounts for one-third to one-half of the sediment in Ohio waterways.

The intent of this study is to review soil conservation policy and programs in the U.S., to attempt to establish the relationship between alternative rotation and tillage systems and the amount of sediment entering Lake Erie harbors and Ohio State Park Lakes, and to estimate the related dredging costs and foregone boating value loss. Hopefully, this research effort will help identify farming systems (rotation/tillage) that can significantly

reduce soil erosion and its subsequent off-farm sediment costs. Such information will help in the development of effective soil conservation programs which assure sustainable agricultural and related environmental systems in Ohio and elsewhere.

1.1 Soil Conservation Policy and Programs in the U.S.

Although the evidence of cropland erosion and its resulting damage was noted much earlier, the effort to create and implement soil conservation policies in the U.S. started with the 1935 Soil Conservation Act. This act declared soil erosion to be a menace, and established soil conservation programs on a permanent rather than emergency basis (9). However, since the act was passed, programs implemented have been predominantly oriented toward the on-site (maintain productivity) costs of soil erosion. It has been estimated that \$15 to \$30 billion has been spent on the on-site oriented soil conservation programs which include education, technical assistance, and cost sharing (5). Clark et. al. (1985) indicate that much of the federal assistance has been used to increase productivity rather than to decrease erosion. Thus, soil conservation programs retained strong characteristics of production enhancement in an era of agricultural commodity surpluses generated by the intense use of petrochemical inputs coupled with sagging demand for agricultural output.

Another characteristic of soil conservation policy since the 1935 Act has been the equitable allocation of funds, despite the erosion status of each region. The 1977 National Resources Inventory Report indicates that 52 percent of assistance funds was allocated to lands eroding at less than 5 tons per acre, and 78 percent of subsidies spent to induce planting to less erosive crops went to land eroding at less than 5 tons per acre (7). The same report indicates that 25 percent of these subsidies went to land eroding at less than

1 ton per acre. Accordingly, many of the past programs were not effective in reducing soil erosion, since soil conservation targeting was not used in allocating funds.

The process of soil conservation targeting evolved with a series of modifications in farm legislation in the 1980s. These modifications include the 1981 restriction of cost sharing funds and the Food Security Act of 1985 (FSA85). Both bills were designed to help target soil conservation efforts on lands eroding at more than three times the soil loss tolerance (T) (7). The traditional cost sharing approach had been purely voluntary, and the federal assistance depended on the erosion-control techniques that individual farmers proposed to adopt (5). Clark et.al (1985) indicate that in the purely voluntary programs much of the money was spent not only on less eroding lands, but for productivity improvements. The effectiveness of many cost-sharing programs was undermined by the lack of assistance in operation and maintenance costs.

Under the 1985 Food Security Act, two policy elements were introduced: the cross-compliance and the conservation reserve programs. The cross-compliance threatens exclusion of farmers from government programs for non-compliant land uses. On the other hand, the conservation reserve has been claimed as the

..."foundation of all future agricultural and conservation policy" (19). It has twin goals:(a) to reduce soil erosion damages, both on-site productivity losses and off-site costs, such as sedimentation, and (b) to reduce agricultural production capacity and thereby support crop prices. To achieve these goals, the Secretary of Agriculture is empowered to enter into 10-year contracts with owners of highly erodible cropland that preclude commercial use of that land for the life contract and require that acceptable conservation cover-grass or trees be established and maintained. The maximum acreage authorized in the legislation is 45 million to be enrolled over a 5-year period from 1985; totally 70 million acres are eligible nationwide" (7).

Both the 1981 cost-sharing and the 1985 Food Security Act are intended to reduce soil erosion from the more erosive cropland. These two approaches utilize a T-value threshold of eligibility as a policy guide. The T-value is defined as "the maximum rate of annual soil erosion that will permit a high level of crop productivity to be obtained economically and indefinitely i.e., approximately 200 years (AAEA, 1986, p.49).

Many agricultural economists have reservations about T-value thresholds. Some express their support for the concept of a T-value because it is based on the notion of intergenerational equity. The precept is that each generation should so manage the soil as to avoid imposing higher production costs on subsequent generations (3). Other economists like Ervin et. al. (1984) and Runge et. al. (1986) argue that T-value is an unreliable proxy for both on-site and off-site impacts. Ribaud (1986) supports this argument by saying that the optimal distribution of effort in soil conservation varies when both off-site and on-site effects are taken into consideration. Such an argument is relevant because using T-value and size of off-site impacts as a guide to policy may result in conflict, as off-site benefits and productivity benefits may not occur in the same geographic areas (18). As defined, the T-value was designed to protect on-farm soil productivity, rather than identify sites where erosion imposes socially unacceptable off-farm costs (3).

In response to on-site productivity and off-site impacts, scientists, farmers and the general public have recently expressed considerable interest in "Alternative Agriculture" also called "Sustainable Agriculture". Sustainable agriculture differs from conventional agriculture, which treats resource conservation and environmental quality as constraints to profit maximization (1). Alternative agriculture addresses multiple objectives such as increasing profits and maintaining the environment and places emphasis on substitution of rotations, labor, management, biological pest control, etc. for petrochemical inputs and

monoculture practices (1). New funding for alternative agriculture research was provided by the 1985 Food Security Act, and although its centers, institutes, and foundations are established in several states including Iowa, Wisconsin, and California, much remains to be done in providing a research base for recommending profitable and environmentally sound farming systems.

1.2 Overview of Soil Erosion External Costs in Ohio

In Ohio, the large portion of sediment comes from 77 percent of the 15.4 million acres of cropland (12), producing row crops. Beyond farms, such sediment imposes costs on a wide variety of receptors such as Lake Erie harbors, State Park lakes and the Ohio River. *The primary focus of this study is directed toward estimating the magnitude of soil loss and related off-site dredging costs and boater value loss from alternative tillage and rotation systems. The analysis will focus on tillage and rotation systems for a sample of five Ohio counties with watersheds draining into four State Park Lakes.*

Several studies of the external costs of soil erosion have been conducted in Ohio and are located on a map in Figure 1. Macgregor (1988), used the Ohio Department of Natural Resources State Park Lakes visitations and dredging data to estimate the boater value losses and dredging costs due to sedimentation in 46 State Park Lakes. His findings indicate an average boater value loss in the 46 lakes of \$ 0.34 per ton of sediment, but the values ranged from \$.006 to \$9.03 per ton of sediment (see Appendix A) which emphasizes the need for targeting of soil conservation funds based on off-site economic impacts. The average cost was \$1.29 to dredge one ton of sediment in 11 State Park lakes where dredging was being done in 1987. An analysis of Army Corps of Engineers data for 1985-87 on quantities of sediment dredged and contractual costs for 10 Lake Erie harbors

Figure 1

Ohio Soil Erosion Off-Site Impact Studies



is presented in Appendix B and shows an average cost of \$2.90 per ton of sediment dredged. A similar analysis shows an average dredging cost in the Ohio River at \$2.52 per ton of sediment. Forster and Bardos (1986), found an average water treatment cost of \$0.002 per 1,000 gallons for sediment removal in 12 public water treatment plants in Western Ohio. Figures for the dredging of drainage ditches in six Northwest Ohio counties indicate costs of \$ 1.87 per ton of sediment removed (9).

For the purpose of targeting site-specific conservation programs, the aggregate estimates presented by Clark et. al. (1985) and Ribaudo (1986) fall short of providing regional or local estimates of off-site costs. Thus, MacGregor (1988), Bardos (1986), and Forster et. al.(1985) provide needed site-specific information for targeting site-specific soil conservation.

Data bases available for addressing site-specific off-farm impacts are from EPA's PEMSO data set and a USDA Soil Conservation Service data base. The PEMSO data base was developed in the 1980s to inventory all-important physical characteristics of Ohio land. It provides average rates of gross soil erosion for different land types. As a rule, agricultural land erodes at a higher rate than range land, forest land and other lands (as illustrated by statewide average soil loss rates of 4.0, 2.9, and 1.8 ton per acre, respectively). Unlike the PEMSO data base, the USDA Soil Conservation Service data base was developed for agricultural land use only. It provides detailed average soil loss rates for farming systems, specifically rotation/tillage systems. Further information about the USDA Soil Conservation Service data base is provided in the methodology section.

For both data bases, erosion estimates are generated using the Universal Soil Loss Equation (USLE) and its characteristics are defined by USDA (1977) as follows:

$$A = R * K * LS * C * P$$

where

A = the estimated soil loss in per acre

R = the rainfall erodibility factor

LS = the slope length/gradient factor

C = the cropping management factor

P = the erosion control practice factor.

Wischmeier (1976) argued that USLE was designed to predict soil loss from sheet and rill erosion on the field and also to help compute total annual soil loss within a given watershed as long as the estimates of the six factors can be derived. Predicted soil loss estimates are the key factor in the calculation of sediment deposition rates and their related off-farm impacts.

Previous studies by Hemmer (1981) and Diallo (1989) indicate that many soils are responsive to crop rotations and reduced tillage, and that net incomes of farmers using these systems are equal to or greater than the conventional systems. For example, Hemmer compared economic returns of alternative tillage systems for corn production on selected soils in the Western Lake Erie Basin. Data were collected from 416 operations for 1978-80. Average net returns per acre for conventional, chisel plow, minimum tillage, and no-till were \$141.75, \$147.26, \$156.96, and \$142.22, respectively.

1.3 Objectives and Scope of this Study

The primary objective of this study is to determine whether or not soil loss and related dredging costs and boating value losses are responsive to the use of alternative rotation/tillage systems. Specific objectives of this study are the following: (a) to estimate average predicted soil loss for each rotation/tillage system by sample county (using USDA

Soil Conservation Service data base); (b) to use sediment delivery ratios to estimate the amount of sediment deposited into State Park Lakes; and (c) to estimate the subsequent annual average dredging costs and boater value loss for each rotation/tillage system by sample county. This comparison is made to identify agricultural land practices which could effectively reduce soil erosion and its related off-site costs without imposing unacceptable economic hardship on farmers.

This study is based on a sample of 4 State Park Lakes located in *Adams, Butler, Preble, Shelby, and Highland* counties. The sample for which there exists a data base on dredging, boater value loss and USLE based county soil loss from the SCS/USDA includes Adams Lake, Acton Lake, Lake Loramie and Rock Fork Lake. The organization of the study includes the methodology and procedures in the next section followed by a discussion of major findings, implications, limitations, and further research needs.

Methodology and Procedures

2.1 Classification of Rotation/Tillage Systems

The systems in this analysis are based on those developed in the Ohio Farm Longitudinal Survey by the Department of Agricultural Economics and Rural Sociology, at the Ohio State University. Rotation/tillage systems used in this analysis are presented in the following chart:

Tillage

Rotation	T1	T2	T3	T4
R1	R1T1	R1T2	R1T3	R1T4
R2	R2T1	R2T2	R2T3	R2T4
R3	R3T1	R3T2	R3T3	R3T4
R4	R4T1	R4T2	R4T3	R4T4

where

R1 = Continuous row crop

R2 = Row crop-small grain

R3 = Row crop-small grain-pasture

R4 = Small grain-pasture

T1 = The field is moldboard (spring or fall) plowed with secondary tillage. It is called conventional tillage.

T2 = The field is fall or spring chisel plowed with secondary tillage.

T3 = Only secondary tillage is performed before planting. It is also called minimum tillage.

T4 = No primary nor secondary tillage is performed. Planting is undertaken with a no-tillage planter.

Of the 16 foregoing rotation/tillage systems in the chart, only two, i.e. R1T1 and R1T4, will be utilized for the analysis that follows. The two tillage systems (T1 and T4) were found statistically significant in explaining variation in Ohio farm profitability in research by Diallo (1989).

Conventional farming systems in Ohio are generally highly specialized and emphasize high yields through fertilizers, pesticides, and other off-farm purchases (1). Because some feel that conventional agriculture has failed to guarantee at least minimum adverse effects on human health and the environment, there have been calls for "Alternative farming

systems". Alternative farming systems range from systems including soil tests, integrated pest management and capital inputs, to systems that seek to minimize their use through appropriate rotations (1) and tillage systems. This study will emphasize how alternative tillage and rotation systems, used as soil conserving measures, affect off-site dredging costs and boater value loss in the watersheds draining into Adams Lake, Acton Lake, Lake Loramie and Rocky Fork Lake.

2.2 Description of Drainage Basins and Watersheds

Adams Lake. It is built on Lick Creek within the Ohio Brush Creek Watershed in the Southwest Tributary Basin. The PEMSO system indicates that the basin does not affect the lake, nonetheless, topographic maps show that about 4.21 square miles of the watershed (located in West Union) drains into Adams Lake. The soil types includes Bratton, Opequon, Lawshe and Nicholson.

Acton Lake. Acton Lake is located in Preble and Butler counties on Four Mile Creek. It is drained by Seven Mile Creek Watershed within the Great Miami Basin. The PEMSO system indicates that the upstream drainage affects the lake. Almost the entire watershed, or 94.94 square miles, drains into Acton Lake. The predominant soil types in the watershed include Russel, Miamian, Xenia and Wynn.

Lake Loramie. This lake is located in Great Miami River Basin within the Middle Great Miami and Dayton Watershed. Using the PEMSO system, approximately 74.59 square miles of the Middle Great Miami Watershed drains into Loramie Lake. The soil types within drainage area are Blount and Pewamo for Lake Loramie.

Rocky Fork Lake. Located in Highland County, Rocky Fork Lake is drained by 109.44 square miles of Paint Creek Watershed. Soil types within the drainage area are Haubstadt, Otwell and Negley.

2.3 Data Sources and Sample Selection

The data base used for estimating soil loss from rotation/tillage systems (R1T1 and R1T4) is derived from computer generated data by the USDA Ohio Soil Conservation Service. The computer program used to generate this data is called "Soil Loss Tabulator". It is a spreadsheet which takes into account each Universal Soil Loss Equation parameter to estimate soil loss from a rotation/tillage system for each soil type by county. It also provides a soil loss tolerance (T) which helps soil conservationists to classify farming systems as more or less erosive. Gross soil loss from R1T1 and R1T4 were pooled together and generated 20 observations. For each soil type draining into sample lakes, an average soil loss was estimated (Table 1). However, Lauesche soil is not included in our analysis because of the missing data on related soil loss. Other sources of data include the earlier discussed analysis of Corps of Engineers dredging data, and boating values from Macgregor (1988).

2.4 Estimating Sediment Deposition, Dredging Costs, and Boater Value Loss

Table 1 presents gross soil loss for each soil type under R1T1 and R1T4. It is important to estimate the proportion of eroded soil transported and deposited into lakes. The estimation of sediment deposition into surface water implies the application of

Table 1. Predicted Soil Loss From Sheet and Rill Erosion For Watersheds Draining Into Four Sample Lakes (tons per acre).

State Park Lakes	Watersheds	Soil Types	T-Toler	Area	Soil Loss	
					R1T1	R1T4
Adams Lake	Ohio Bush Creek	Bratton Opequon Lousche Nicholson	3.5	<i>up & down</i> NA	29.4	5.5
			1.0	NA	214.9	40.6
			NA	NA	NA	NA
			4.0	611	12.15	2.3
		Bratton Opequon Lousche Nicholson	3.5	<i>contouring</i> NA	16.8	3.2
			1.0	NA	209.3	39.6
			NA	NA	NA	NA
			3.0	611	6.1	1.15
		Russel Miamian Xenia Wynn	5.0	<i>Butler County</i> 48121	12.4	2.6
			4.75	32117	32.2	1.9
			5.0	36202	8.9	1.9
			3.75	42409	19.2	4.3
Acton Lake	Seven Mile Creek	Russel Miamian Xenia	5.0	<i>Preble County</i> 7060	17.6	3.8
			5.0	37024	48.3	2.9
			5.0	3549	3.7	0.8
		Blount Pewamo	3.0	108628	9.3	1.9
			5.0	41157	2.3	0.5
Lake Loramie	Middle Great Miami and Dayton	Haubstadt Otwell Negley	3.0	19111	34.0	1.4
			3.0	8312	53.5	11.6
			3.0	7452	39.6	8.9
Rocky Fork Lake	Paint Creek	Haubstadt Otwell Negley	3.0	19111	34.0	1.4
			3.0	8312	53.5	11.6
			3.0	7452	39.6	8.9

NA = Not available.

sediment delivery ratios. The sediment delivery ratio approach helps to approximate the proportion of eroded soil deposited into State Park Lakes. The amount of sediment deposited is estimated as the sediment delivery ratio times gross soil loss from each rotation/tillage system.

Baker (1985), studying water quality impacts of intensive row-crop production in the Lake Erie Basin, used sediment delivery ratios of 9.2 percent for Maumee River, 8.5 percent for Sandusky River, and 8.2 percent for Honey Creek. The sediment delivery ratio approach used in this study is described in MacGregor(1988) based on OEPA (1980). According to OEPA (Ohio Environment Protection Agency), the sediment delivery ratio for gross erosion is formulated as follows:

$$SDR = 10^{ss}$$

where

SDR = dredging costs

$ss = 1.534 - [0.142 * \log 10]$

DRAIN = drainage basin area (sq. mi)
for the lake.

Therefore, estimated sediment delivery ratios within the four lake basins are 14.45 percent, 12.53 percent, 12.68 percent, and 12.44 percent for Adams Lake, Acton Lake, Lake Loramie, and Rocky Fork Lake, respectively. Multiplying these sediment delivery ratios by gross soil erosion from Table 1 yields the sediment deposition values shown in Table 2. Multiplying sediment deposition by site-specific costs of dredging as is illustrated in MacGregor (1988), per ton dredging costs are \$2.19 for Adams Lake, \$2.07 for Acton Lake,

Table 2. Predicted Sediment Entering Four Sample Lakes by Rotation/Tillage System (tons per acre).

State Park Lakes	Counties	Soil Types	SDR	<u>Sediment Delivered</u>	
				R1T1	R1T4
			(%)	(tons/acre)	
Adams Lake	Adams	Bratton	14.45	4.25	0.79
		Opequon		31.05	5.86
		Lausche		NA	NA
		Nicholson		1.75	0.33
		Bratton		2.43	0.79
		Opequon		30.24	5.87
		Lausche		NA	NA
		Nicholson		0.88	0.33
Acton Lake	Butler	Russel	12.53	1.55	0.32
		Miamian		4.03	0.24
		Xenia		1.11	0.24
		Wynn		2.40	0.54
	Preble	Russel		2.20	0.48
		Miamian		6.05	0.36
		Xenia		0.43	0.10
Lake Loramie	Shelby	Blount	12.68	1.18	0.24
		Pewamo		0.29	0.06
Rocky Fork Lake	Highland	Haubstadt	12.44	4.23	0.92
		Otwell		6.65	1.44
		Negley		4.93	1.11

NA = Not available.

\$1.99 for Lake Loramie, and \$2.03 for Rocky Fork Lake. This in turn yields dredging costs per rotation/tillage system presented in Table 3. Similarly, related boater value loss per rotation/tillage is given by sediment deposition times site-specific boater value losses (e.g., \$4.41 per ton for Adams Lake, \$0.26 per ton for Acton Lake, \$0.17 per ton for Lake Loramie, and \$0.07 per ton for Rock Fork Lake) developed by Macgregor (1988) and presented in Table 4.

Summary and Conclusions

3.1 Major Findings

As observed in Table 1, the difference in soil losses per acre from the rotation/tillage systems are appreciable. Soil loss is lower with R1T4 (continuous row crop under no-till) and higher with R1T1 (continuous row crop under conventional system). Also there are large differences in soil loss levels among soil types: Opequon soil is highly erodible (214.9 tons per acre per year), Otwell soil is next (53.5 tons per acre per year), followed by Miamian, Negley, Haubstdat, Bratton, Wynn and Russel soils. Xenia and Pewamo are the least erodible soil types with a yearly soil losses of 3.7 tons and 2.3 tons per acre.

Figures in Table 1 reveal that most soil types erode at rates exceeding the USLE based tolerance rates. When comparing R1T1 and R1T4 across the four study watersheds, R1T4 shows potential for soil loss decreases and may be recommended by soil conservationists to reduce soil erosion and its related off-site impacts.

Table 3. Estimation of Dredging Costs in Four Sample Lakes.

State Park Lakes	Counties	Soil Types	Site Specific Dredging Cost	Dredging Cost by <u>Rotation/Tillage</u>	
				R1T1	R1T4
			(\$/ton)	(\$/acre)	
Adams Lake	Adams	Bratton	2.132	9.32	1.73
		Opequon		68.00	12.84
		Lausche		--	--
		Nicholson		3.84	0.72
		Bratton		2.43	1.73
		Opequon		30.42	12.87
		Lausche		--	--
		Nicholson		1.77	0.72
Acton Lake	Butler	Russel	2.0674	3.20	0.66
		Miamian		8.33	0.49
		Xenia		2.29	0.49
		Wynn		4.96	4.16
	Preble	Russel		4.55	0.99
		Miamian		12.51	0.74
		Xenia		0.89	0.20
Lake Loramie	Shelby	Blount	1.9946	2.35	0.48
		Pewamo		0.58	0.12
Rocky Fork Lake	Highland	Haubstadt		8.60	1.87
		Otwell		13.52	2.93
		Negley		9.45	2.26

Table 4. Estimation of Boater Value Loss by Roation/Tillage in Four Sample Lakes.

State Park Lakes	Counties	Soil Types	Site Specific Boater Value Loss	Boater Value Loss by Rotation/Tillage	
				R1T1	R1T4
			(\$/ton)	(\$/acre)	
Adams Lake	Adams	Bratton	4.4073	18.73	3.48
		Opequon		136.85	25.83
		Lausche		--	--
		Nicholson		7.71	1.45
				<i>contouring</i>	
		Bratton		10.71	3.48
		Opequon		133.28	25.87
		Lausche		--	--
Acton Lake	Butler	Nicholson	0.2574	3.88	1.45
		Bratton		10.71	3.48
		Opequon		133.28	25.87
		Lausche		--	--
	Preble	Nicholson		3.88	1.45
		Bratton		10.71	3.48
		Opequon		133.28	25.87
		Lausche		--	--
Lake Loramie	Shelby	Nicholson	0.1738	3.88	1.45
		Bratton		10.71	3.48
		Opequon		133.28	25.87
		Lausche		--	--
Rocky Fork Lake	Highland	Nicholson	0.0686	3.88	1.45
		Bratton		10.71	3.48
		Opequon		133.28	25.87
		Lausche		--	--

Estimates from Table 2 reveal that shifting from T1 to T4 with continuous row crop (R1) under up-and-down hill cultivation leads to large decreases in sediment loads entering the lakes. Estimated sediment loads from Opequon, Otwell, Miamian, Negley, Haubstadt, Bratton, Russel, and Wynn soils decrease by 25.49 tons, 5.21 tons, 4.74 tons (average for Butler and Preble counties), 3.82 tons, 3.31 tons, 3.46 tons, 1.46 tons, and 1.86 tons per acre each year, respectively. If the acres of soil types under cultivation are taken into account, soil conservationists should pay special attention to soil types such as Haubstadt, Blount, Pewamo, Russel, Miamian, Xenia, and Wynn which appear to be eroding above sustainable rates, and they also deliver a large amount of sediment to State Park Lakes. It is evident that Haubstadt soil, because of the relatively large area it covers, delivers more sediment to Adams Lake than Otwell and Negley which encompass a smaller area but have higher soil loss per acre.

Related dredging costs and boater value losses follow the same trend as soil loss and sediment delivered decreases, i.e. they decrease with the shift from conventional tillage (T1) to no-till (T4). What is different is that dredging costs are generally higher than boater value losses among the lakes, except for Adams Lake which shows boater value losses relatively higher than dredging costs (Tables 3 and 4). Due to the differences in soil loss, soil types exhibit variation in dredging costs ranging from \$0.58 per acre (Pewamo) to \$68.05 per acre (Opequon). Similarly, losses of boater values ranges from \$0.05 per acre (Pewamo) to \$136.85 per acre (Opequon). It should be noted that the soils in the watersheds selected for study are generally eroding at rates greater than the statewide average tolerance of 4 tons per acre per year.

3.2 Conclusions

The primary purpose of this paper was to determine whether or not soil loss and its related dredging costs and boating value losses were responsive to alternative rotation/tillage systems. Results revealed that shifting from conventional tillage to no-till results in a significant reduction of sediment yield and its related dredging costs (i.e., \$8.32) and boating value losses (i.e., \$9.14). Boating value losses per ton of sediment also vary considerably between the four sample lakes e.g., \$.04 to \$2.72.

Among soil types, Opequon yields the highest sediment deposition and its related dredging costs (i.e., \$68.06 per acre under R1T1 and \$12.84 per acre under R1T4). Its related boater value loss is also the highest (i.e., \$136.85 per acre under R1T1 and \$25.83 per acre under R1T4). Also Opequon, Miamian, Negley, Haubstadt, Bratton, Wynn, and Russel soils erode at more than the 4 ton threshold under R1T1. The same results are registered under R1T4, except for Miamian and Russel soils.

3.3 Implications, Limitations, and Further Research

Analysis of tillage effects on off-farm costs indicates that conventional tillage yields a higher amount of sediment, dredging costs, and boater value losses than no-till. These results are consistent with previous studies by Hemmer (1981) which found conventional tillage to also be less profitable on selected soils. However as proponents of alternative agriculture look for ways to reduce off-site sediment damage, there will likely be trade-offs with farm level net income.

Although estimates were made of the likely areas and soil types draining into each study lake, it would be better to conduct a field study to determine these areas more

precisely. In addition, the findings in this paper are based on four State Park Lakes (located in 5 counties) out of 46 Ohio State Park Lakes for which data were available. The size of the lake sample limits suggests that any generalization of findings to the state level must be done with caution.

Future research needs to integrate data on profitability of alternative farming systems with the evidence on downstream economic impacts on harbor, lakes, and water treatment plants. This will allow the determination of economically optimum solutions on a watershed or larger societal basis. This effort is currently underway as part of a new research project at OSU (Hatch 945) on "The Economics of Sustainable Agriculture."

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Appendix A

Total Value Loss (VAL) and Value Loss per Ton of Sedimentation (VALT).

State Park	SEDIN	AREA2	VAL	SEDINT	VALT
	(ac-ft)	(acres)	(\$\$)	(tons)	(\$/ton)
Adams Lake	1.437	32.7	7589	2787	2.7235
Alum Creek	14.024	3387	715	27185	0.0263
A.W. Marion	2.117	130	2812	4105	0.6851
Barkcamp	3.448	117	5088	6866	0.7411
Blue Rock	1.224	14.2	14881	2437	6.1059
Buck Creek	11.142	2120	907	21598	0.0420
Buckeye Lake	8.043	2800	496	16014	0.0310
Burr Oak	15.063	664	3916	29992	0.1306
Caesar Creek	41.865	2830	2554	81155	0.0315
Cowan Lake	13.874	670	3575	26894	0.1329
Deer Creek	27.351	1277	3698	53020	0.0697
Delaware	24.929	1300	3311	48325	0.0685
Dillon	96.558	1560	10686	192261	0.0556
East Fork	57.293	2120	4666	111064	0.0420
Findley	1.082	84	2224	2098	1.0602
Forked Run	2.928	104	4860	5830	0.8337
Gr.L. St. Mary's	9.221	12813	124	17874	0.0070
Guilford	2.177	320	1174	4334	0.2710
Harrison Lake	2.507	107	4045	4860	0.8323
Hocking Hills	0.285	21.1	2334	568	4.1092
Hueston Woods	30.950	560	9541	59997	0.1590
Indian Lake	15.775	5063	538	30579	0.0176
Jackson Lake	4.983	221	3893	9922	0.3923
Jefferson Lake	3.186	18	30554	6343	4.8169
Kiser Lake	2.120	380	963	4110	0.2344
Lake Alma	0.457	63	1253	910	1.3763
Lake Hope	5.360	130	7118	10672	0.6670
Lake Logan	7.130	340	3620	14197	0.2550
Lake Loramie	7.219	829	1503	13995	0.1074
Lake White	42.734	351	21019	85089	0.2470
Madison Lake	2.915	57	8830	5652	1.5624
Mosquito	9.113	7850	200	18144	0.0110
Mt. Gilead	0.470	15.7	5170	911	5.6725
Paint Creek	55.601	770	12466	107784	0.1157
Pike Lake	11.336	11.4	171665	22571	7.6056

Appendix A continued.

Total Value Loss (VAL) and Value Loss per Ton of Sedimentation (VALT) continued.

State Park	SEDIN	AREA2	VAL	SEDINT	VALT
	(ac-ft)	(acres)	(\$\$)	(tons)	(\$/ton)
Pymatuning	10.826	14528	129	21557	0.0060
Rocky Fork	31.820	2100	2616	61684	0.0424
Salt Fork	56.570	3010	3245	112638	0.0288
Scioto Trail	2.814	9.6	50605	5603	9.0317
Shawnee	6.997	59.5	20301	13932	1.4572
Stonelick	4.105	152	4662	7957	0.5859
Strouds Run	5.655	161	6064	11261	0.5385
Tar Hollow	1.528	14.3	18451	3043	6.0632
Van Buren	1.029	55	3229	1994	1.6192
West Branch	4.959	2650	323	9875	0.0327
Wolf Run	3.490	214	2815	6949	0.4052

Appendix B

Lake Erie Harbor Dredging Tonage and Costs, 1985-87.

Habor		Tons Dredged	Cost	Average Cost/Ton
Ashtabula	85	102,420.45	\$ 305,077.00	\$2.98
Cleveland	85	260,326.66	\$1,838,756.88	
	86	415,701.55	1,512,100.00	
	87	<u>435,380.99</u>	<u>1,737,860.00</u>	
		1,111,409.20	\$5,088,716.88	\$4.58
Conneaut	86	82,627.27	\$ 198,132.00	\$2.40
Fairport	85	183,912.74	\$ 654,479.00	\$3.56
Huron	85	55,685.41	\$ 352,000.58	
	87	<u>150,376.38</u>	<u>410,997.00</u>	
		206,061.79	\$ 762,997.58	\$3.70
Lorain	85	198,483.56	\$ 637,635.00	
	86	243,512.50	716,012.00	
	87	<u>170,946.38</u>	<u>534,473.00</u>	
		612,942.44	\$1,888,120.00	\$3.08
Rocky River	85	57,873.09	\$ 297,408.00	\$5.14
Sandusky	85	247,322.79	\$ 804,656.10	
	86	270,247.45	692,035.00	
	87	<u>101,794.88</u>	<u>260,796.80</u>	
		619,365.12	\$1,757,487.90	\$2.84
Toledo	85	1,060,105.20	\$3,320,064.13	
	86	1,497,510.52	2,560,827.00	
	87	<u>1,298,699.05</u>	<u>\$2,836,192.00</u>	
		3,856,314.77	\$8,717,083.13	\$2.26
Vermillion	85	112,194.83	\$ 457,428.00	\$4.08

Average cost \$20,126,929.49 ÷ 6,945,121.70 = \$2.90

